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DETERMINATION OF DTL CONFIGURATIONS

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Summary

A computer code (TDL) has been developed for quickly designing and evaluating different drift-tube linac (DTL) configurations. Inputs to the code include the power losses on reference DTL components determined previously by a computer code such as SUPERFISH. The scaling parameters for the new DTL configuration are beta (particle velocity), accelerating gradient, synchronous phase angle, transit-time factor, and the number of cells per DTL tank. Resulting calculations determine cell size, rf power losses, beam energy, and DTL length of the new configuration. A complete new configuration can be generated in a few seconds on an Apple II computer. Accuracy of this code is within 1% of the more sophisticated code PARMILA.

Discussion

A reference cell design from SUPERFISH, or the equivalent, for a constant-gradient tank is used to establish the proper scaling for power-loss calculations. The assumption is made that the power density on all conducting surfaces scales with the square of the accelerating gradient at that axial position. Drift-tube (DT) body lengths are allowed to vary as needed to meet the beam-dynamics requirements, but all other dimensions, such as DT stem diameters, DT body diameters, post couplers, and tank diameters must be unchanged from the reference SUPERFISH run. The power density and alignment length are determined by scaling with power density and axial length.

An iterative procedure is used to determine energy gain per cell. The average beta over that cell determines the cell length. Power loss on the DT body is determined by averaging gradients in the two adjacent cells, scaling from the reference calculation, and scaling DT length with beta. Drift-tube-stem losses and post-coupler losses are determined by scaling with the square of the relative gradient from the reference cell. Post couplers are positioned at every other DT. Power losses on the tank wall are scaled exactly like the drift-tube-body losses. Losses on the tank end walls are determined by direct scaling from the reference-cell end-wall losses. Beam power is simply the beam energy times the beam current. The sum of all ohmic losses plus the beam power gain determines the minimum rf power that must be delivered to the tank.

The input parameters from the reference design include the following:

- Power loss on a DT stem at reference cell
- Power loss on reference post coupler
- Accelerating gradient in reference cell
- Particle beta in reference cell
- Power density on tank wall
- Tank diameter
- End-wall power loss

Additional run parameters are input from the keyboard or internal subroutines. The run-dependent parameters include those listed below:

- Input beam energy
- Input beam current
- Number of DT cells
- Maximum deliverable rf power
- Initial accelerating gradient
- Final accelerating gradient
- Initial synchronous phase
- Final synchronous phase
- Transit-time factor (can be a function of cell number or beta)

From these input reference conditions, reasonably accurate estimates may be made for any other DTL operating at the same frequency. In particular, this code allows the determination of output beam energy, cell length, accelerator length, and rf power requirements.

Advantages of using this code are as follows:

- A single-cell SUPERFISH run can be made as soon as the operating frequency is chosen.
- This code can then be used to determine the entire DTL structure. At present no form of longitudinal intertank matching is provided, but that can be added easily if the matching is provided by adjusting the synchronous phases at the first and last cells.
- This code can be used to study the tradeoffs needed in specifying such parameters as synchronous phase angle, total rf power, input and output energies, number of drift tubes, accelerating gradient, break points between multiple tanks, and overall accelerator length.
- Exact beam-dynamics calculations should be run at the conclusion of the above process to verify generation of a suitable output beam.

Some of the variables used in the program are listed below:

- AEW -- End-wall power loss for the reference cell
- GT -- Beta for the reference cell
- D -- Reference cell tank diameter
- EI -- Accelerating gradient in the reference cell
- P1 -- Power loss on DT stem in reference cell
- P2 -- Power loss on post coupler in reference cell
- P1 -- Power loss on DT body in reference cell
- TK -- Reference-cell power density on tank wall
- AF -- Final synchronous phase angle in tank
- A1 -- Initial synchronous phase angle in tank
- B -- Beta of beam at current cell
- D1 -- Energy gain per cell
- EO -- Accelerating gradient at current cell
- LF -- Final accelerating gradient in tank
- E1 -- Initial accelerating gradient in tank
- G -- Relativistic gamma of the beam
- L -- Cell length - beta * lambda
- N -- Current cell number
- NI -- Power loss in one cell length of tank wall
- PH -- Synchronous phase at current cell
- PN -- Power loss on DT
- PU -- Power loss on post coupler

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PX -- Power loss on DT stem
SM -- Power loss on end walls
ST -- Total rf power required
T -- Cell output energy
TU -- Transit-time factor

Following is a listing of the described computer code written in Microsoft BASIC.

1 REM PROGRAM TDTL
2 REM TEI CALCULATE RAMPED-FIELD DTL
3 REM BY ROGER TENNANT & OAVE SCHNEIDER
4 REM DATE LAST MOD 2/25/85
10 GOSUB 20000: REM PRINT HEADER
20 GOSUB 15000: REM SET UP REFERENCE DATA & DEFAULT VALUES
30 GOSUB 5000: REM INPUT RUN PARAMETERS
40 C改变SUB 1000: REM CALCULATE AND PRINT
999 END
1000 LPRINT "INITIAL ACCELERATING GRADEIENT " ;E1 ;" MV/M"
1010 LPRINT : LPRINT "INITIAL PHASE ANGLE " ;AI ;" DEGREES"
1020 LPRINT "COLUMN HEADINGS ARE: " ; LPRINT "Cell #, Length, Cell length, OT Power loss, Stem Power loss, Wall losses, Post coupler losses": LPRINT
1030 DT = O
1040 REM LOOP COMPUTES DELTA OF BEAM OVER CELL LENGTH IN MEV, DT
1050 REM COMPUTES VALUE OF GAMMA
1060 G=1+(T+OT/2)/939
1070 E0 = El+(EF-El)*N/NC
1080 PH=AI+(AF-AI)* N/NC
1090 SM = (AEi// 1000) * ((El /T)-2 + (EF /ET)-2)
1100 REM COMPUTES VALUE OF BETA
1110 OB=SQR(l-1/(G' 2))
1120 GOSUB 2000 :REM DETERMINE TRANSIT-TIME FACTOR
1130 EA = EO* TU* COS (I-H* 3.1416 / 180)
1140 REM COMPUTE'S VALUE OF CELL LENGTH, L
1150 L=B*LD:02~L*EA
1160 IF ABS (OT - D2) < .0001 GOTO 1200
1170 A=0.2
1180 GOTO 1030
1190 IF ABS (OT - D2) < .0001 GOTO 1200
1200 =O.2
1210 GOTO 1030
1220 REM PRINTS THE ACTUAL POWER LOSS ON A DT STEM BASED ON HALF FROM PRESENT AND LAST CELL
1260 I = 1 + 1
1270 IF I > 2 GOTO 1310:REM GM115 EVERY OTHER POSI COUPLER
1280 GOTO 1060
1290 Z = O
1300 P = El B / RT) - ((EO / ET) 2) / 1000
1310 PW = + P 2 + PL / 2
1320 PS = PI ((EO / ET) - 2) / 1000
1330 PX = PS / 2 + PW / 2 REM CALCUlATES THE ACTUAL POWER LOSS ON A DT STEM BASED ON HALF FROM PRESENT AND LAST CELL
1340 L = B* LD:02~L*EA
1350 IF ABS (OT - D2) < .0001 GOTO 1200
1360 IF ABS (OT - D2) < .0001 GOTO 1200
1370 GOTO 1030
1380 P* = P 2 + PD / 2 REM POWER LOSS ON A COUPLER
1390 L = B* LD:02~L*EA
1400 IF ABS (OT - D2) < .0001 GOTO 1200
1410 GOTO 1030
1420 GOTO 1500
1430 LPRINT1
1440 TO * T = 1000 * T
1450 PB = T - 1000 * T - TO
1460 TS = TS + ST:J = 10
1470 LPRINT USING BS$;L2;ST;SD;SS;SC;SNT;SM
1480 LPRINTT
1490 ST = O:SO = O:SD = O:SC = O:SNT = O:K = K + 1
1500 IF N = NC + 1 GOTO 1530
1510 LPRINT USING BS$;L2;ST;SD;SS;SC;SNT;SM
1520 LPRINT USING BS$;L2;ST;SD;SS;SC;SNT;SM
1530 LPRINT USING BS$;L2;ST;SD;SS;SC;SNT;SM
1540 TF = "Total Accelerator Length = " ; FN R3(L2):" meters"
1550 LPRINT "Total Power Required = " ; FN R3(ST):" KW"
1560 LPRINT "Total Power on OTs = " ; FN R3(SD):" KW"
1570 LPRINT "Total Power on OT stems = " ; FN R3(SS):" KW"
1580 LPRINT "Total Power on Post Couplers = " ; FN R3(SC):" KW"
1590 LPRINT "Total Power on walls = " ; FN R3(SM):" KW"
1600 LPRINT "Total Accelerator Length = " ; FN R3(L2):" meters"
1610 LPRINT "Total Power on walls = " ; FN R3(SM):" KW"
1620 LPRINT "Total Power on OT stems = " ; FN R3(SS):" KW"
1630 LPRINT
1640 RETURN
2000 TU = 125.4764 * B / 2 - 56.6223 * B / 2 + 8.2056 * B / 4.7036
2010 RETURN
5000 PRINT: INPUT "INPUT BEAM ENERGY, BEAM CURRENT " ;T,11
5010 PRINT : INPUT "INITIAL ACCELERATING GRADIENT, FINAL ACCELERATING GRADIENT " ;E1,EF
5020 PRINT : INPUT "INITIAL PHASE ANGLE, FINAL PHASE ANGLE " ;AI,AF
5030 PRINT: INPUT "INPUT MAX RF POWER PER TANK (KW)" ;PM
5040 PRINT:INPUT "INPUT MAX RF POWER PER TANK (KW)" ;PM
5050 TO = T * 1000 * 11
5060 RETURN
5099 RETURN
15000 REM REFERENCE PARAMETERS FROM SUPPRF."
15010 PT = 1128: REM POWER LOSS ON DT BODY (WATTS)
15020 PT = 838: REM POWER LOSS ON DT STEM (WATTS)
15030 P = 409: REM POWER LOSS ON POSI COUPLER (WATTS)
15040 ET = 1.947: REM ACCELERATING GRADIENT (MV/M)
15050 BT = .066: REM BETA IN REFERENC CELL
15060 YK = 2.2: REM POWER DENSITY ON TANK WALL (WATTS/SQ CM)
15070 D = 42: REM TANK DIAMETER (CM)
15080 K = 5000: REM POWER LOSS ON TANK END WALLS (WATTS)
15090 LD = 0.7059: REM FREE SPACE WAVELENGTH (M)
15100 REM INITIALIZE CALCULATION PARAMETERS
15110 K - 1:Z = 0: I = 0: N = 0:PL = 0
15120 PS = 0:TS = 0:PM = 0:SS = 0:SD = 0:SC = 0:SM = 0
15999 RETURN
20000 REM INITIAL HEADING
20010 AS=" ###/###":REM PRIN1 IMAG1 STRINGS
20015 DEFW= R3(4)-IN1(1000)+0.5/100
20020 PRINT"This program will determine the appropriate DTL configuration if "
20030 PRINT "correct reference parameters are input."
20040 PRINT:PRINT"Input conditions must be set at subroutine 15000."
20050 PRINT"Set initial conditions, then run program and respond to questions."
29000 RETURN
Conclusions

A wide variety of DTL trade-off studies can be accomplished quickly with the TDTL computer code described above. One study determined efficiency (defined as the output beam power divided by the delivered rf power) as a function of the average on-axis accelerating gradient. The results are shown in Fig. 1. Another investigation, summarized in Fig. 2, compared accelerator length, accelerating gradient, and number of klystrons required for a hypothetical accelerator. Once the desired accelerator configuration is determined, more exact beam-dynamics calculations can be done, using a more precise computer code such as PARMILA. The TDTL computer code offers the advantage of user-friendliness and the ability to run efficiently on virtually any microcomputer.

Fig. 1. Power efficiency versus average accelerating gradient.

Fig. 2. Accelerator length (meters) versus rf power tubes required.